



[Case Report]

Usefulness of monitoring the oxygen reserve index in the pediatric intensive care unit

Naoki Shimizu, Shigetoshi Ogiwara, and Osamu Saito

*Department of Pediatric Emergency & Critical Care Medicine, Tokyo Metropolitan Children's Medical Center,
Tokyo 183-8561.*

(Received May 11, 2018, Accepted August 1, 2018, Published February 10, 2019.)

Abstract

Advanced warning of desaturation based on child-specific physiology is needed. Pulse oximetry does not indicate downward trends in arterial partial pressure (PaO_2) until the percutaneous arterial oxygen saturation (SpO_2) begins to fall. Therefore, SpO_2 cannot provide advanced warning of desaturation events. The oxygen reserve index (ORI) is a new, noninvasive method of monitoring oxygen reserves. The clinical usefulness of the ORI has been reported in anesthesiology but reports from pediatric critical care are still few in number. The current study is the first to demonstrate the usefulness of the ORI for the management of sick children in a pediatric intensive care unit. To improve outcomes for sick children, using the ORI for advanced warning of desaturation is recommended.

Key words: oxygen reserve index, children, anesthesia, sedation, functional residual capacity, risk management

I. Introduction

Over 40 years have passed since the introduction of pulse oximetry by Aoyagi et al. [1-3]. Despite its significance, pulse oximetry does not indicate downward trends in arterial partial pressure (PaO_2) until the percutaneous arterial oxygen saturation (SpO_2) begins to fall. Thus, this technology is limited by the fact that SpO_2 cannot provide advanced warning of desaturation events.

The oxygen reserve index (ORI) is a new, noninvasive method of monitoring the oxygen reserve,

such as the PaO_2 level above an SpO_2 of 100%. The ORI is a pulse oximeter-based nondimensional index that ranges from 1 to 0 as arterial partial pressure (PaO_2) decreases from around 200 to about 80 mmHg and is measured by optically detecting changes in venous saturation (SvO_2) after arterial saturation (SaO_2) has reached the maximal level.

The clinical usefulness of the ORI has been reported in anesthesiology [4-7], but reports from pediatric critical care field are few in number. The current study is the first to demonstrate the usefulness of the ORI for sick children in a pediatric intensive care unit (PICU).

II. Cases

Case 1: A 1-year-old boy was intubated and ventilated due to retropharyngeal abscess. He was admitted to our PICU. After the stabilization, we

Address correspondence to Dr. Naoki Shimizu,
Department of Pediatric Emergency & Critical Care Medicine,
Tokyo Metropolitan Children's Medical Center, 2-8-29,
Musashidai, Fuchu, Tokyo 183-8561, Japan.
Phone: +81-42-300-5111. Fax: +81-42-312-8160.
E-mail: naoki_shimizu@mac.com

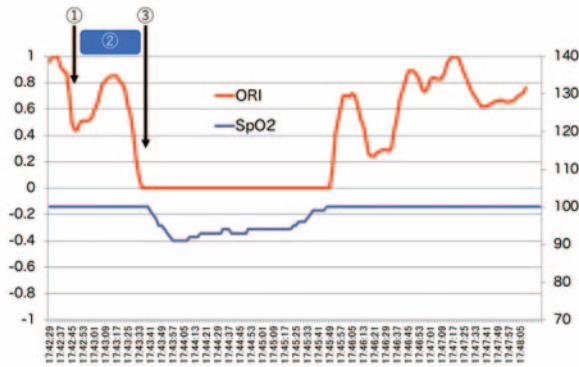


Fig. 1 Trend in the ORI and SpO₂ during nasopharyngeal end-tracheal intubation

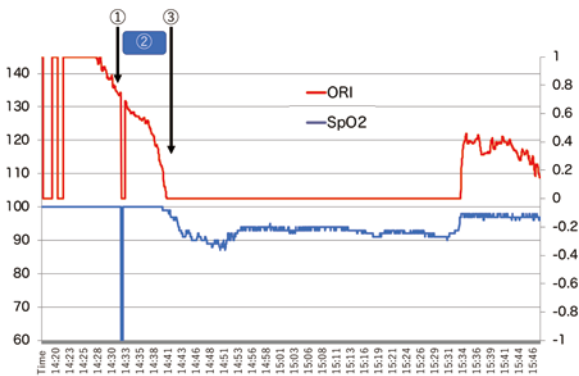


Fig. 2 Trend in the ORI and SpO₂ during the management of a case with pulmonary hypertension

performed naso-tracheal intubation on the assumption that artificial ventilation would be required for several days. We used the ORITM (MASIMO, Japan) in conjunction with SpO₂ monitoring (Fig. 1). During the procedure, before the drop in the SpO₂, (③) we noticed a drop in the ORI reading (①). We stopped the procedure and re-oxygenated him (②) and later re-attempted intubation. The desaturation event was minimized, and the procedure was completed safely.

Case 2: A 1-year-old boy was admitted to our PICU with pulmonary hypertension (PH). We used the ORITM with SpO₂ monitoring (Fig. 2). Before desaturation caused by a PH attack (③), we observed a drop in the ORI (①), based on which we were able to oxygenate this patient slightly earlier than is normally possible (②). The desaturation event was relatively mild and was prevented from becoming more serious.

III. Discussion

Cardiac arrest or bradycardia are serious complications of hypoxia during patient management in the PICU. To prevent these potentially fatal outcomes, monitoring devices are always useful; however, we need to realize the limitations of these devices.

Pulse oximetry based on SpO₂ measurements is one of the most useful monitoring tools in the PICU; however, venous pulsation may become more prominent in situations with lower perfusion or massive body movement. The very limited performance of pulse oximetry under these conditions has presented a major clinical problem[8]. Furthermore, pulse oximetry is unable to indicate downward trends in the PaO₂ until the SpO₂ begins to fall. Thus the SpO₂ cannot provide advanced warning of desaturation events[6].

Functional residual capacity (FRC) is one of the determinants of oxygenation[9]. For reasons having to do with child physiology, FRC in children is smaller than in adults and prone to faster desaturation[10,11]. Additionally, the smaller FRC in children is maintained by physiological stenosis at the level of the cricoid and dynamically by tachypnea[12]. Thus, the pediatric FRC is not only small but also very unstable. Since sedatives, narcotics, and/or muscle relaxants often used in the PICU tend to diminish the FRC further, the risk of hypoxia increases correspondingly.

Based on these special features of child physiology, advanced warning of desaturation is needed. Though the ORI may provide the answer to this need, this device is not well distributed not only in Japan but also all over the world yet. The cases discussed here demonstrate that the ORI allowed us to re-oxygenate the patients before a desaturation event and minimize the severity of desaturation. Although further study is needed to validate our findings, this case report demonstrated the usefulness of the ORI in pediatric critical care.

The ORI can also be used in the pediatric general ward, emergency room, and imaging suite. In the imaging suite in particular, conscious sedation of children is often done. As described above, sedatives diminish the FRC and thereby increase the risk of

hypoxia in children during imaging procedures. To ensure greater safety for sick children not only in the PICU but in pediatric medicine generally, using the ORI for advanced warning of desaturation is recommended.

Contributors

NS, SO and OS managed the cases. SO measured ORI and analyzed data. NS, SO, and OS contributed to writing of the report. Consent to publication was obtained from the family. Publication was approved by the Institutional Review Board of Tokyo Metropolitan Children's Medical Center. Authors thank Mr. James Robert Valera for his assistance with editing the manuscript.

Conflict of interest

The authors declare that they have no conflicts of interest regarding the content of this article.

References

- 1) Severinghaus JW, Honda Y. (1987) History of blood gas analysis. VII. Pulse oximetry. *J Clin Monit* 3, 135-8.
- 2) Aoyagi T, Miyasaka K. (2002) The theory and applications of pulse spectrophotometry. *Anesth Analg* 94 (1 Suppl), S93-5.
- 3) Miyasaka K. (2003) Do we really know how pulse oximetry works? *J Anesth* 17, 216-7.
- 4) Yoshida K, Isosu T, Noji Y, Hasegawa M, Iseki Y, Oishi R, Imaizumi T, Sanbe N, Obara S, Murakawa M. (2017) Usefulness of oxygen reserve index (ORITM), a new parameter of oxygenation reserve potential, for rapid sequence induction of general anesthesia. *J Clin Monit Comput* Sep 27.
- 5) Scheeren TWL, Belda FJ, Perel A. (2017) The oxygen reserve index (ORI): a new tool to monitor oxygen therapy. *J Clin Monit Comput* Aug 8.
- 6) Applegate RL 2nd, Dorotta IL, Wells B, Juma D, Applegate PM. (2016) The relationship between oxygen reserve index and arterial partial pressure of oxygen during surgery. *Anesth Analg*, 123, 626-33.
- 7) Szmuk P, Steiner JW, Olomu PN, Ploski RP, Sessler DI, Ezri T. (2016) Oxygen reserve index: a novel noninvasive measure of oxygen reserve--a pilot study. *Anesthesiology* 124, 779-84.
- 8) Miyasaka K. (2002) Pulse oximetry in the management of children in the PICU. *Anesth Analg* 94 (1 Suppl), S44-6.
- 9) West JB. (1995) *Respiratory Physiology -the essentials* 5th edition. Williams and Wilkins 12-14pp.
- 10) Lumb AB. (2012) *Nunn's Applied Respiratory Physiology*. Churchill Livingstone 257pp.
- 11) Miyasaka K. (1986) Use of non-invasive oximetry during the induction of anesthesia in children in Payne JP. Severinghaus JW. (Ed) *Pulse Oxymetry*. Springer Verlag 95-105pp.
- 12) Berman LS, Fox WW, Raphaely RC, Downes JJ Jr. (1976) Optimum levels of CPAP for tracheal extubation of newborn infants. *J Pediatr* 89, 109-12.